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The Use of Subset Selection in Combined-Array Experiments to Determine Optimal Product or Process Designs

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Abstract

In his pioneering work on product and process improvement, Taguchi (1986) emphasizes two types of factors that effect product quality: "control factors" are those variables that can be (easily) manipulated by the manufacturer and "noise factors" are those variables that represent either different environmental conditions that affect the performance of a product in the field *or* (uncontrollable) variability in component parts or raw materials that affect the performance of an end-product. For experiments to improve product or process design, Taguchi advocates using statistical designs that are products of highly fractionated orthogonal arrays in the control and noise factors. In the case of product design, for example, the goal of such experiments is to determine conditions under which the mean product quality is independent of the noise factors. While some of Taguchi's proposals have been controversial [Box (1988)], the basic viewpoint that he advocates has been applied widely and with many successes [Taguchi and Phadke (1984)].

A number of authors have proposed statistical refinements to the Taguchi methodology [Shoemaker, Tsui, and Wu (1991); Nair *et al.* (1992); Myers, Khuri, and Vining (1992), for example]. One of these proposals is to use combined-arrays in the control and noise factors to design quality improvement experiments rather than Taguchi's product-arrays. At the expense of confounding higher-order interactions, carefully chosen combined-arrays allow the experimenter to determine interactions among the control factors and interactions among the noise factors, as well as the critical control factor by noise factor interactions that allow one to minimize the effect of noise factors in product quality. A second proposal is to apply response surface methodology to the combined-array data to identify parsimonious models for the quality character-

istic(s) of interest; these models can be used to select the levels of the control factors.

This paper shows how the subset selection philosophy introduced by Gupta (1956, 1965) can be fruitfully used to screen for control factor combinations in quality improvement experiments based on data analytic models. Bechhofer, Santner, and Goldsman (1995) give an overview of this field and present procedures to accomplish other important experimental goals. We focus on the case where the quality control characteristic of interest is to be *maximized*. Section 2 introduces a study typical of those in the food industry to improve the quality of a cake mix recipe by manipulating its ingredients, the control variables, when the baking is performed under a variety of time and oven temperature conditions, the noise variables. The procedure is developed based on a model relating the control and noise variables to the results of a taste test from a 2^{5-1} combined-array experiment. Section 3 introduces the subset selection procedure proposed for identifying the recipe that maximizes the minimum mean taste test response where the minimum is taken over the levels of the oven temperature $\times$ baking time variables. The critical value required to implement the procedure is determined. Some generalizations and caveats are presented in the final section.